

An Interactive Graph-Based Automation Assistant: A Case Study to Manage the GIPSY's Distributed Multi-tier Run-Time System

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Abstract

The GIPSY system provides a framework for a distributed multi-tier demand-driven evaluation of heterogeneous programs, in which certain tiers can generate demands, while others can respond to demands to work on them. They are connected through a virtual network that can be flexibly reconfigured at run-time. Although the demand generator components were originally designed specifically for the educative (demand-driven) evaluation of Lucid intensional programs, the GIPSY's run-time's flexible framework design enables it to perform the execution of various kinds of programs that can be evaluated using the demand-driven computational model. Management of the GIPSY networks has become a tedious (although scripted) task that took manual command-line console to do, which does not scale for large experiments. Therefore a new component has been designed and developed to allow users to represent, visualize, and interactively create, configure and seamlessly manage such a network as a graph. Consequently, this work presents a Graphical GMT Manager, an interactive graph-based assistant component for the GIPSY network creation and configuration management. Besides allowing the management of the nodes and tiers (mapped to hosts where store, workers, and generators reside), it lets the user to visually control the network parameters and the interconnection between computational nodes at run-time. In this paper we motivate and present the key features of this newly implemented graph-based component. We give the graph representation details, mapping of the graph nodes to tiers, tier groups, and specific commands. We provide the requirements and design specification of the tool and its implementation. Then we detail and discuss some experimental results. **Keywords:** graph-based management, visualization, GIPSY network, demand-driven computation, GUI

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1 Introduction

The GIPSY (General Intensional Programming System) project is an ongoing research project developed at Concordia University. Its initial goal was to investigate on a general solution for the evaluation of programs written in the Lucid intensional programming family of languages using a distributed demand-driven evaluation model. In order to meet the flexibility goals of the project, the system has been designed using a framework approach integrating a Lucid compiler framework, as well as a demand-driven run-time system framework.

In its educative model of execution, the system assumes the presence of demand generators, as well as a demand workers. Each demand generated is paired along with the context in which it is made and is uniquely identified. The demands are migrated using a communication node that enables the connection between demand generators and demand workers. Through the communication node, any demand worker can pick-up demands, compute its resulting value, and send it back to the communication node to be picked up by the generator.

Notably, the framework has demonstrated its flexibility by having the run-time system put to use in the demand-driven distributed evaluation of programs not involving the Lucid language. The work presented here goes in this direction and makes abstraction of the intensional programming aspect of the project and concentrates on the demand-driven evaluation of heterogeneous programs. We concentrate on showing how a virtual network of demand-driven computational nodes can be represented graphically at run-time, enabling the user to map the demand-driven computation nodes over an underlying physical network of computers, and to control their execution and connectivity at run-time.

In the current implementation, the node's connectivity is expressed in a set of configuration files. Upon starting, a node reads its configuration file and establishes its own connection according to the information contained in the configuration file. The configuration can be changed at any time, so that a node can reconfigure its connectivity at run-time.

A manager node, which acts as a supernode, has been implemented to manage a GIPSY network. It enables new node(s) to automatically establish connection with it and receive commands from it. Therefore, enabling the manager node to remotely change the configuration of any registered node. The virtual network is thus constructed from the interconnection of the generators, workers, communication, and manager nodes, the later being able to establish the connectivity between the three first ones. All communication between nodes, including commands exchanged for configuration changes, are using the same demand-driven communication mode.

The rest of this paper is organized as follows: Section 2 gives on overview of the GIPSY Framework and its multi-tier architecture, the GIPSY run-time system and finally discusses the related work. Section 3 summarizes the objectives of this work. Section 4 presents how currently the GIPSY run-time system is being managed, discusses the design and implementation of the proposed solution and evaluates the results of some conducted experiments. Then, Section 5 concludes the paper and points out new research direction planned as future work.

2 Background

2.1 GIPSY Framework

The GIPSY run-time system is a distributed multi-tier and demand-driven framework. It mainly consists of a set of loosely coupled software components enabling the evaluation of programs in a distributed demand-driven manner. The run-time system is composed of the following basic entities [17]: (a) **A GIPSY tier** is an abstract and generic entity. Each tier instance is a separate thread (one or more) that runs within a registered process, namely (GIPSY node), and represents a computational unit that contribute to the distributed computation. Tiers cooperate in a demand-driven mode of computation; (b) **A GIPSY node** is a registered process that hosts one or more GIPSY tier instances belonging to different GIPSY instance(s). Node registration is done through a manager tier called the GIPSY Manager Tier (GMT). More specifically, a node is a computer running a *GIPSYNode* process; (c) **A GIPSY instance** is a group of tier instances collaborating together to achieve program execution. It can be considered as a set of interconnected GIPSY tier instances hosted/deployed on one or more GIPSY nodes executing GIPSY programs by sharing their respective resources. A GIPSY instance can be executed across different GIPSY nodes. Moreover, as shown in Figure 1, a GIPSY network is designed as an overlay network where network nodes, GIPSY tiers, are organized in a cluster called GIPSY instance. A GIPSY tier can be seen as a virtual network node and hosted on a GIPSY node. In such a network, the mapping between a GIPSY node and a physical node is made upon starting and registering the node through the GMT.

2.1.1 Multi-Tier Architecture

In [17], a distributed multi-tier architecture has been defined and adopted in the implementation of GIPSY run-time system. The architecture inherits some of the peer-to-peer network architecture principles, e.g (1) no single-point of failure: any tier or node can fail without fatally affecting the system; (2) nodes and tiers can seamlessly join/leave the network by adding/removing them on the fly as computation is happening; (3) demands are propagated without knowing where they will be processed or stored; (4) available nodes and tiers can be affected at run-time to the execution of any GIPSY program while other nodes and tiers could be computing demands for different programs. The multi-tier architecture is composed of four distinct tiers: (a) a Demand Store Tier (DST) that acts as a middleware between tiers in order to migrate demands, provides persistent storage of demands and their resulting values (demands caching), and exposes Transport Agents (TAs) used by other tiers to connect to the DST; (b) a Demand Generator Tier (DGT) that generates demands according to the declarations and resources stored in the GEER generated for the program being evaluated. The DGT maintains a local demand processing dictionary pool that contain the definitions required to formulate demands; (c) a Demand Worker Tier (DWT) which processes demands by executing method defined in such a dictionary. The DWT connects to the DST, retrieves pending demands and returns back the computed demands to the DST; (d) a General Manager Tier (GMT) (see Figure 1), as its name implies, locally and remotely controls and monitors other tiers

(DGT, DWT and DST) by exchanging system demands. Furthermore, the GMT can register new nodes, move tier instances from one node to another, or allocate/deallocate tier instance from/on a registered node.

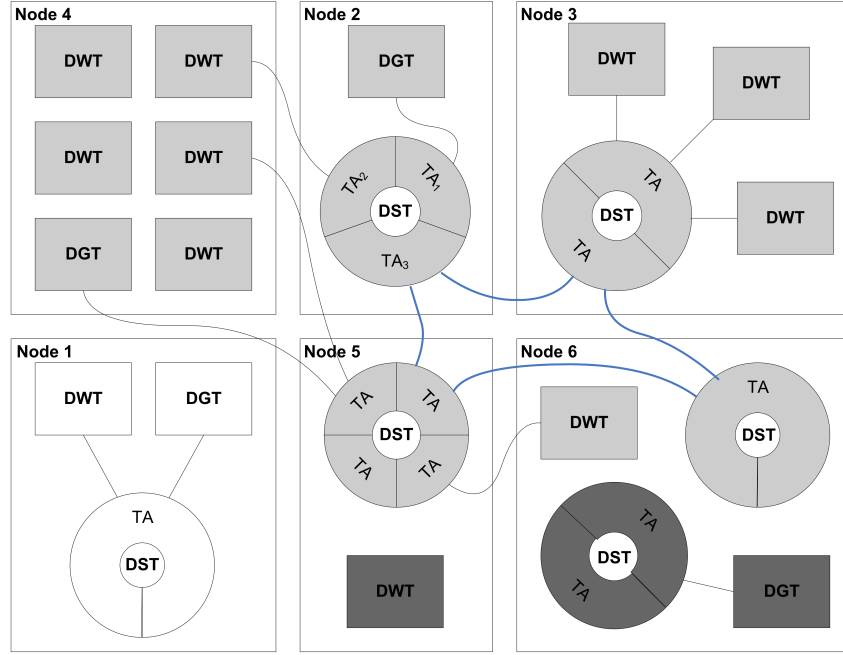


Figure 1: Example of a GIPSY Nodes Network [17]

2.1.2 Demand Types and States

A demand is a run-time request asking for a value of certain identifier defined in a GIPSY program. Demands are migrated to other tiers using the DST. There are three types of demands: (a) intensional demands, which are generated for the evaluation of a GIPSY program by a generator. GIPSY programs are written in a declarative style, where an identifier is defined as an expression using other identifiers defined in a multidimensional context space [17]. All demands for GIPSY identifiers contain the context in which they are made, and their evaluation depend on this context. The GIPSY program also uses an algebra of procedures that can be called during evaluation, which are called at run-time and become procedural demands; (b) procedural demands which are generated by the DGT when it encounters a procedural function call during the GIPSY program evaluation. Procedural demands are processed by the DWT; (c) system demands, in turn, are issued by the GMT for run-time management purposes and include demands for monitoring and controlling tiers at run-time. It is worth mentioning that system demands are requests for managerial tasks e.g. demand for node registration, tier allocation and deallocation. In contrast, intensional demands and procedural demands are computational demands, i.e. demands that are generated during the evaluation process of a specific GIPSY program.

In the GIPSY environment, each demand has a state and demand states are used to manage and propagate demands. The state transitions are managed by the demand store

tier DST, who is responsible for demand migration between generator and worker tiers. We distinguish three possible states as follows: (a) **Pending**: a pending demand is a demand that has been issued by a tier to the demand store and not yet picked by another tier for further processing. Pending demands are sent to generators and workers when they notify their availability for processing [17]; (b) **Processing**: a processing demand is a demand that has been grabbed by a tier from the demand store and its evaluation still being processed. This state is assigned by the demand store in order to make sure that the same demand is grabbed by only one tier for processing. When a tier goes out of service, all its associated processing demands are put back to the pending state by the demand store, ensuring a fail-safe behavior [17]; (c) **Computed**: indicates that a demand has been computed. When a tier grabs a demand and is finished computing its corresponding value, it sends back the result to the demand store, that stores it in place of the initial demand and marks it as computed. Any further demands generation with the same context will result in the store to directly respond with the resulting value, thus saving computation time [17].

2.2 Graphical GMT Tool Support for the GIPSY Run-time System

Here we provide some details how the graph-based tool we developed assists with the automation of the startup sequence and management tasks of the system.

Configuration. The tier instantiation process has a flexible design and has been implemented using Java Reflection [5] and the Factory design pattern [4]. It uses a configuration-based system to instantiate tiers on the fly. Generic configuration instances are stored in files and their settings can be easily updated and tailored to a specific tier’s implementation requirements. Configurations contain a set of key-value pairs where the key denotes the name of the configuration property while the values could be anything from a service name, port number, IP address, etc. Such a configuration system eliminates the need of writing or adapting source code to reflect a specific tier configuration. The properties stored in the **Configuration** object determine the tier class to instantiate and consist of different settings interpreted by the tier implementation class. Upon receiving a tier instantiation request, the **TierFactory** inspects the configuration instance to determine which tier implementation class to instantiate using Java Reflection [5].

Bootstrapping. as mentioned earlier, a GIPSY network consists of a set of interconnected GIPSY nodes each hosting GIPSY tiers mapped to physical machines where the GIPSY run-time is deployed. Such a network is managed by a GIPSY manager tier (GMT) that enables nodes registration to the network and tier allocation on the registered nodes. The bootstrap process of the GIPSY manager tier starts a registration demand store that is used solely for the exchange of system demands with the nodes and tiers allocated in the GIPSY network managed by this manager tier. Thus, system demands and computational demands are exchanged using different communication channels. Any computer deploying the GIPSY node run-time system can send a registration request to the man-

ager tier, enabling this manager tier to remotely connect and control the allocation of various tiers on the registered nodes. After tiers are allocated to the registered nodes, the manager tier can connect the different tiers together, and eventually instruct a generator to start the demand-driven evaluation of a GIPSY program. Even after execution is started, the manager tier can accept new nodes registrations, or allocate/deallocate new tiers on any registered node that it manages and make newly allocated tiers to contribute to a program's evaluation on the fly [8, 7].

GIPSY Node Registration. When a node wants to join the network, first, a GIPSY node issues a request to the GMT expressed as `NodeRegistration` system demand having *pending* as state. Upon receiving a `NodeRegistration` demand, the GMT assigns a DST to the GIPSY node who issued the request. Afterward, the GMT saves the node registration information in a `GMTInfoKeeper` object and sends back a `RegistrationResult` demand having *computed* as state and containing the DST information and the assigned node ID. Finally, the GIPSY node processes the result and uses the information contained in the demand to establish a connection to the assigned DST. Establishing such connection creates a communication channel for further exchange of system demands.

Tier Allocation. Tiers are allocated inside a previously registered GIPSY node. The process of tier allocation is performed through the operation of the GMT using a pair of system demands: `TierAllocationRequest` and `TierAllocationResult`. Both demands share the same demand signature but have different states: *pending* and *computed* respectively. The following information needs to be specified in the `TierAllocationRequest` demand: the node identifier of the GIPSY node where the tiers to be allocated, the type of the tier and how many tier instances are to be allocated. When the allocation process is completed a `TierAllocationResult` demand is triggered and contains a set of tier registrations. Each tier registration contains information such as the tier identifier, which is internally assigned by the GIPSY node.

Tier Deallocation. Tier deallocation consists of removing previously allocated tiers. Similarly to the case of the tier allocation process, two system demands `TierDeallocationRequest` and `TierDeallocationResult` are issued by the GMT to deallocate tiers upon user's request. The type and the ID of the tier to be deallocated are embedded in a `TierDeallocationRequest` and sent to the `GIPSYNode` process to deallocate the tier specified.

2.3 Related Work

Related work by several researchers on visualization of load balancing, configuration, formal systems for diagrammatic modeling and visual languages and the corresponding graph systems are presented in [20, 19, 1, 2, 10]. They all define key concepts that are relevant to our visualization mechanisms within GIPSY and its corresponding General Manager Tier [7].

3 Objectives

The GIPSY framework has been designed in a modular manner but has a lot of configurable components; hence, the need of an automation solution for configuring and managing GIPSY deployment components is crucial. Moreover, prior to this work, the run-time system was managed using primarily a command-line interface. The project should provide an integrated tool that allows the user to: create a GIPSY network and configure its components (GIPSY instances, tiers and nodes); save/load a GIPSY network configuration; start/stop GIPSY nodes and register them with the GMT, and allocate/deallocate GIPSY tiers; dynamically visualize GIPSY nodes and tiers and inspect/change their properties at run-time; change tiers connectivity at run-time; increase the usability of GIPSY run-time system as a whole; provide means and semantics for scheduling, validation, and visual mapping to Lucid programs. The GMT is the central element of our system from the user’s perspective. It enables to handle the managerial tasks related to the configuration and functioning of a GIPSY network. The proposed solution should be transparent and efficient enough in order to enhance the system usability, flexibility, and end-users experience, while maintaining the structure for run-time analysis and scheduling.

4 Solution

4.1 Overview

The solution presented in this paper is a graph-based graphical user interface that provides a set of user interfaces enabling the users to directly interact with the distributed GIPSY run-time system. The main objectives (cf. Section 3) of this work consist of increasing the usability of the run-time system and enabling the user to have full control over the GIPSY network with a minimum of detailed manual intervention. It should be noted that, prior to this work, all the managerial and configuration tasks needed to bootstrap a GIPSY network required the user to manually execute sheer number of commands and scripts. In this work, we designed the graphical GMT component that aims at allowing the user to manage and operate the entire GIPSY network seamlessly by translating simple graphical user interactions into complex message passing between the underlying deployment components. Our solution enables the user to easily create, configure, and control a GIPSY network through a graph-based interface. GIPSY tiers are illustrated as connected graph nodes. Tiers’ properties are read from files and stored as `Configuration` objects embedded in the graph nodes. We use graph element shapes to differentiate GIPSY instances and colors to differentiate GIPSY nodes. When the user adds a new tier to the network graph, the color assigned to the tier is associated to the node the tier is assigned to.

According to the GIPSY multi-tier architecture, the DWT, DGT and DST expose software interfaces to be used for their mutual interactions. Since the GMT plays a key role in the GIPSY network management, it provides a handy mechanism for starting and stopping nodes, and allocating and deallocating tiers. In the current run-time implementation, the interaction with the GMT is command-based and is done through a

command-line console UI, with which the user manually bootstraps and controls the nodes and tiers by entering commands the corresponding. Additionally, a set of configuration files with the appropriate settings and properties for each tier type are needed. Before performing any node or tier startup or registration, we assume that a set of configuration files with appropriate settings and properties for nodes each tier type have been created. Typically, in order to start a network, the following sequence of steps should normally be performed: 1. At first, a GIPSY node process should be created; that prompts the user to start a GMT tier. When a GMT is started, the GIPSY node is automatically registered and a registration DST is allocated [7]. The registration DST enables the GMT to receive system demands for further node and tier allocations. This is the initial bootstrapping process that enables all further operations on a GIPSY network. 2. At any time the user can expand the network by adding an additional node locally on the computer where the GMT is executing (and tiers on a remote computer). Upon successful node creation, the user is prompted to register the node to an existing GMT using the `register` command. 3. Then, on any registered node, DSTs are started to allow the propagation of demands between generators and workers, DGTs are registered to generate demands, and DWTs are registered to process the generated demands.

Based on this discussion, the following is a typical list of example commands that are used to interact with the run-time system in order to setup a manual GIPSY network:

1. `start GMT GMTConfigFile.config`

This command starts the bootstrap process explained above, where GMT is the type of the tier and `GMTConfigFile.config` is the configuration file that contains the settings and properties needed to instantiate a GMT tier instance.

2. `allocate NodeID TierType TierTypeConfigFile DSTIndex HowMany`

This command allocates a DGT or a DWT. *NodeID* is the numeric ID of the node where the tier should be allocated, *TierType* is the type of the tier ([DGT, DWT]), *DSTIndex* is the index of the DST, to which the tier in question should connect to and the *TierTypeConfigFile* is the tier-specific configuration file to use.

3. `allocate NodeID DST DSTConfigFile.config HowMany`

This command sends a request to the GMT with the node ID where a DST instance will be allocated, how many DST instances are needed, and a DST configuration file name.

4. `deallocate NodeID TierType TierID1 TierID2 TierIDn`

This command issues a demand to be processed by the GMT to deallocate tiers. *TierType* is the type of the *tierID[1..n]* is tier instances IDs to deallocate in a node specified by its ID.

The GIPSY network configuration process requires the user not only to know all the commands and their exact syntax, but requires to keep track of the IDs of the nodes and tiers. It also requires the user to manually edit the related configuration files. The configuration files contain many configuration elements that are not of importance in the node/tier management process, thus leading to confusion and possible mistakes. Our

newly designed graphical GMT assistant rather allows the user to abstractly manipulate icons and use menu options to effectuate these operations. These GUI operations initiated by the user are then translated by the graphical GMT into the commands similar to the presented earlier. As for the changes to the configuration files, the user is presented through the GUI with only the configuration elements that are relevant in the context of use, thus reducing the information load on the user and reducing the possibility of configuration mistakes. Listing 1 shows the content of a configuration file for a DGT [7]. It provides configuration information such as to which class implementation to instantiate, the number of instances to be created, the mode of communication to use, and a maximum number of demands that can be generated. These configuration parameters are read during startup and will determine the behavior of the generator.

```
# Which implementation of the DGT class to instantiate.
gipsy.GEE.multitier.wrapper.impl=gipsy.tests.GEE.simulator.DGTSimulator
gipsy.GEE.multitier.DGT.DemandDispatcher.impl=gipsy.GEE.IDP.DemandGenerator.jini.rmi.
JiniDemandDispatcher
# 0 Concurrent asynchronously
# 1 User-controlled asynchronously
# 2 Response time tester: synchronously
# 3 Space-scalability tester.
gipsy.tests.GEE.simulator.mode=2
gipsy.tests.GEE.simulator.tester.parameter=1
# Number of instances to be created.
gipsy.tests.GEE.simulator.tester.number=2
# Number of maximum demands.
gipsy.tests.GEE.simulator.demand.payload=32
```

Listing 1: A Sample of DGT Configuration File

4.2 Design and Implementation

Our implementation relies on the graph-based visualization to illustrate a GIPSY network. We represent a GIPSY tiers network as interconnected graph nodes where each such node contains data/properties used in tier-to-tier communication configuration. Such properties are assigned and configured by the user when creating a GIPSY network. The GMT GUI was implemented using the Java JFC/Swing library. The GIPSY's **Configuration** class is used to store different components' configuration. We have selected the Java Universal Network/Graph (JUNG) library to implement the visualization of the management aspect of GIPSY nodes [9, 15]. JUNG is an open-source library for modeling data that can be represented as a graph or a network. JUNG provides many visualization features that can be changed at runtime such as node color, shape, and size. Thus, graph nodes can be grouped together, which enables us to differentiate the nodes by their tier type (DST, GMT, or DWT). Through JUNG, GIPSY nodes are configured while creating a connected graph of nodes and to visualize and manage their activities to alleviate manual complexity of such operations. The GMT GUI addresses the need of the automation of the managerial tasks of the GIPSY run-time system and the configuration of resources.

The implemented features are: 1. create a new GIPSY network as a graph; 2. save/load a pre-configured GIPSY network to/from files; 3. start, register and stop GIPSY nodes by

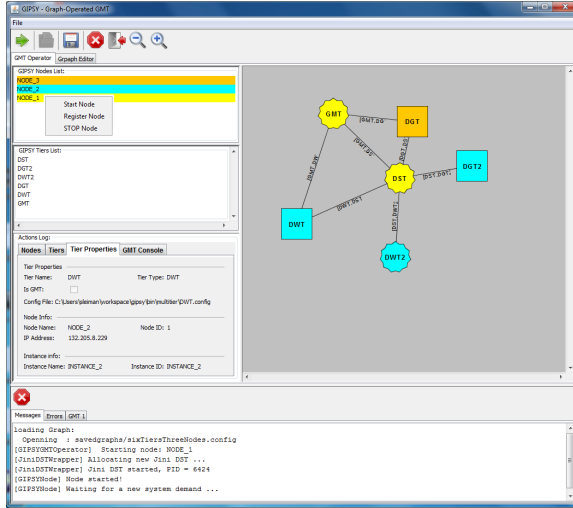
maintaining a color-differentiated list of nodes with their related commands and configurations available in a context menu; 4. allocate and deallocate DSTs, DGTs and DWTs by manipulating icons and context menus; 5. start/stop the demand-driven evaluation process on a DGT through a contextual menu accessed on its icon.

The process of node registration and tier allocation has been embedded into our tool, and only the most relevant configuration information is shown to the user. Graphical objects representing GIPSY nodes encapsulate their related commands and hold the necessary properties for user inspection or change at setup or run-time. As for GIPSY tier graphical objects, in addition to allocate and deallocate commands, these objects provide a drag-and-drop mechanism used to change the connectivity between tiers on the fly at run-time (see Figure 2(a)). When a new tier or a GIPSY node is added to the network, it is automatically pre-configured and associated with a configuration file with the properties entered by the user (see Figure 2(b)). The GMT GUI is arranged in a tabbed form and provides two main distinct editor and operator views.

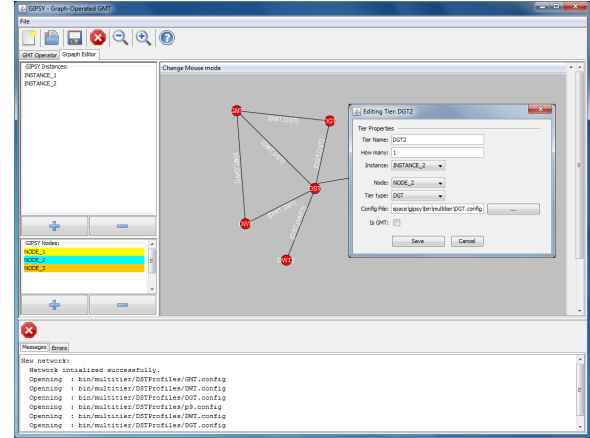
The network graph editor and resource configuration allow to create a GIPSY network or load an existing one. As shown in Figure 2(b), GIPSY instances and nodes are arranged in two lists while GIPSY tiers in a graph illustrating interconnected tiers. Instances, nodes and tiers can be easily added and configured separately. The configuration process is completely automated using dialog boxes allowing the user to fill in the configuration properties of each entity. All data entered is validated allowing only valid values to be accepted. In this editor, two GIPSY tiers could be connected together and their configuration commands automatically generated by drawing a line to connect two graph nodes.

The GMT operator lists context-menu-enabled GIPSY nodes allowing the user to start or stop GIPSY nodes and register them with the GMT by simple mouse clicks. As illustrated in Figure 2(a), GIPSY tiers are shown as connected graph nodes. Tiers belonging to the same GIPSY instance are assigned the same shape. The tier's color determines on which GIPSY node a given tier is hosted on. Moreover, inspection and visualization of any element's properties is possible at run-time. This enables the user, for instance, to know which GIPSY tier is residing on which GIPSY node. The run-time system activities such as the output of GMT, GIPSY nodes and GIPSY tiers, errors, and log messages are displayed in a separate distinct views. This provides better failure traceability and errors troubleshooting while, at the same time, providing useful information related to the overall computation process.

In Figure 3(a) is a set of JUNG-interfaced classes we produced to integrate with and visually represent, load, save, and manage GIPSY networks while in Figure 3(b) we detail the data structures used to internally represent the network graphs and map them to the GIPSY objects and the action items associated with them. **NodeConnection** is a semantically central data structure that links graph elements representing GIPSY tiers (the instances of **GIPSYTier** classes). These connections and tier properties are the actual representation of the graphs that are saved to and loaded from a name:value paired configuration files (e.g. see Appendix B) by **GraphDataManager**. A collection of **NodeConnections** is managed by the **GraphViewer**, and both **NodeConnection** and **GIPSYTier** have action items attached to them that send the aforementioned GIPSY commands to actually do the work via the visual **NodeMenu** and **TierMenu**. Every tier has



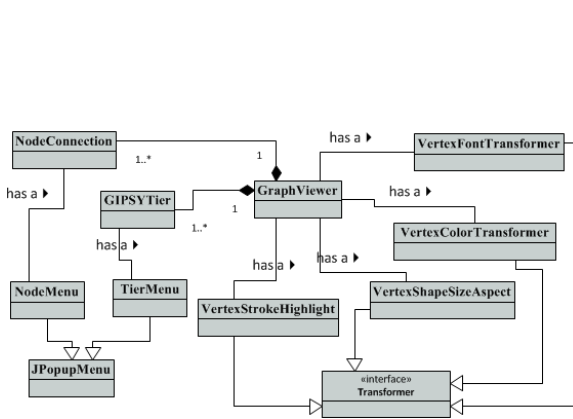
(a) GMT Operator View



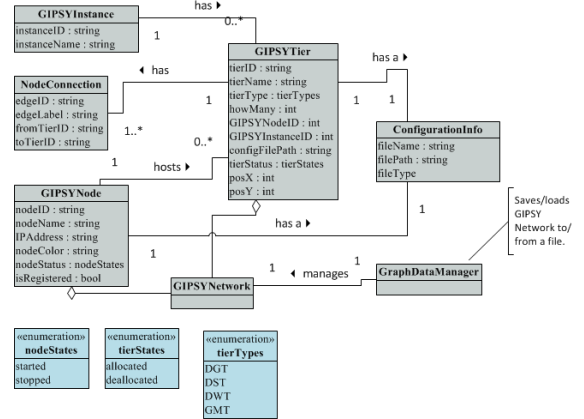
(b) Network Graph Editor View

Figure 2: GMT Operator and Network Graph Editor Views

a color and shape (**VertexColorTransformer**, **VertexShapeSizeAspect**) attached to it based on the **GIPSYNode** they belong to, so it is easier to differentiate and visualize the computing resource allocations. When each graph is loaded, mapping is made, and colors determined, the data structures are handed over to JUNG to do the visual layout.



(a) Visualization Classes



(b) Graph-Related Data Structures

Figure 3: UML Class Diagrams of the Graph-Related Design Aspects

4.3 Results and Discussion

The results are encouraging since they demonstrate the ability of the proposed solution to assist in automation of some management functions GIPSY run-time system. We have first tested with the simulator [18, 7] which allows to generate different types of demands

to be computed. We have then performed some usability testing with another tool, that was recently adapted to be distributively executed over GIPSY – MARFCAT. It is one of the realistic long-running distributed pattern recognition computation processes test cases (e.g. MARF’s pattern recognition pipeline [11] with very large data sets over GIPSY for the static code analysis application for vulnerabilities and weaknesses detection and malware classification [12, 14]. MARFCAT was made to run completely over GIPSY separating the heavy and light work logic across the generator and worker tiers. The tool properly starts up all the indicated components, the network of which were created and the configurations loaded, begins the computation, logs the output to the console, and while computation proceeds, the tier state is properly reflected visually.

While us we were the only users of the proposed PoC tool thus far, by making it public and released along with the GIPSY system and via the demonstration of the tool on the GIPSY simulator and MARFCAT, we hope to gather larger feedback on the tool to improve its usability further while weeding out known bugs.

In Appendix A we summarize a complete demo procedure/manual for a creation of a specific application to run over the GIPSY network for demonstration purposes.

Platforms Tested. We tested the tool in various operating system platforms to ensure the portability is maintained: Windows XP SP3 32-bit, Windows 7 32-bit and 64-bit; Scientific Linux 6.2 32-bit and 64-bit, and Ubuntu Linux 11.03 32-bit under VMware; MacOS X 10.5 32-bit and 64-bit; Oracle JDK 6 and 7; OpenJDK 6; Apple JDK 6.

Implications. The implications of this work are multifold. First, the usability and management aspects of the multi-tier GIPSY network are of obvious mention. Additionally, having the network represented and managed as a graph allows for further reasoning and automatic scheduling [6] and load-balancing of such a network through the graph analysis. Thirdly, since Lucid is a data-flow language and was shown to have one-to-one correspondence with the data-flow graphs (DFGs) [16, 3, 13], the tool opens up more possibilities for diagrammatic programming and program-graph-execution-network translation model for detailed analysis and verification of Lucid-based programs with the added visualization benefit.

5 Conclusion and Future Work

We have presented a graph-based GUI implementation for the simplification of the management of the GIPSY run-time system components. The presented tool is proving to be an effective solution assisting with management automation of GIPSY software artifacts distributed across multiple physical machines forming an overlay network. Our solution relies on graph-based programming and visualization to represent a GIPSY network. Each graph node represents a GIPSY tier and is pre-configured and loaded with the information needed at run-time. A GIPSY network can be created, configured and saved to a file. The user can establish a connection between pairs of GIPSY tiers by drawing a line to connect two graph nodes. A GIPSY network can be easily bootstrapped and managed on the fly. Many demand generators and workers can be allocated as computation is happening.

While aiming at increasing the usability of the run-time system, our solution allows the user to seamlessly inspect the status and properties of GIPSY nodes and GIPSY tiers at run-time.

The work presented in this paper is to be extended, thus, additional features and improvements are planned. Future work includes a better semantic definitions of the graph manipulation actions, so that any operation on a graph can be translated more easily into the underlying system's commands and be verifiable. We plan to add observers to any graph element, enabling for example to click on a graph link to observe the demands flowing across this link at run-time. Among the planned future works is the continual extension of the current design to support more problem-specific tiers like MARFCAT, e.g. genome sequence alignment, and similar computation problems that need a lot of manual pre-setup to run. We further plan to allow intra-tool (peer) communication to further allow start up nodes on remote computers and not only tiers. Additionally, expose an OpenGL-to-Java remote interface to allow connecting to the tool from any OpenGL-enabled systems remotely, including mobile devices based on iOS and Android.

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A Mini Demo User Manual / “Demo Paper”

In this section we give a brief overview on how to use the graphical PoC tool to create and manage a GIPSY network. We explain how to create and configure a network, how the network is saved/loaded to/from a file, and finally, how the network is being managed in the GMT Operator view.

This section is intended for the demonstration of the tool at the conference with a mini-user manual instructions and operational description. We will show how to create and start a complete GIPSY network for the specific MARFCAT application and perform a complete run of it. We will release the PoC tools, the application, and the source code for the audience and community at large as well.

A.1 Using the Graph editor

The graph editor is used to create a new GIPSY network or to edit an existing one.

I. *Creating/Editing a GIPSY instance*

Figure 4(a) and Figure 4(b) show how to create a GIPSY instance and edit its information. By clicking on the add button, the user enters a name for the new GIPSY instance to create and clicks save. Double-clicking on an instance in the list of instances allows to edit the instance name in an appropriate dialog.

II. *Creating/Editing a GIPSY Node*

To create a new GIPSY node, click on the “Add” button Figure 4(c), which pops up a dialog to fill in the new node’s properties such as the node name, IP address and color, see Figure 5(a). Upon clicking “Save”, the new node will be added to the list as shown in Figure 5(b). To edit an existing node’s properties, double-click on an item in the node list and a editing dialog will pop up Figure 5(c).

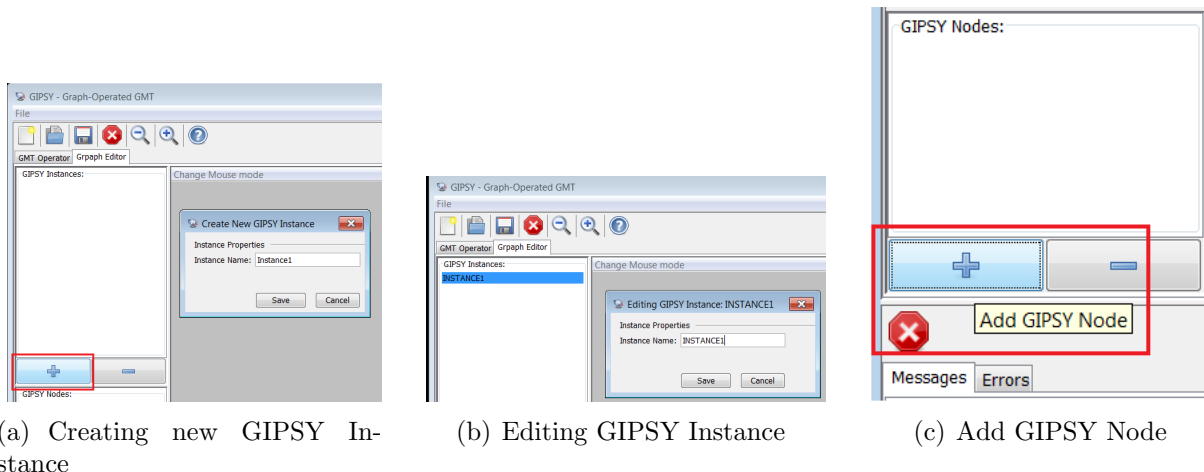


Figure 4: Adding a GIPSY Instance and a GIPSY Node

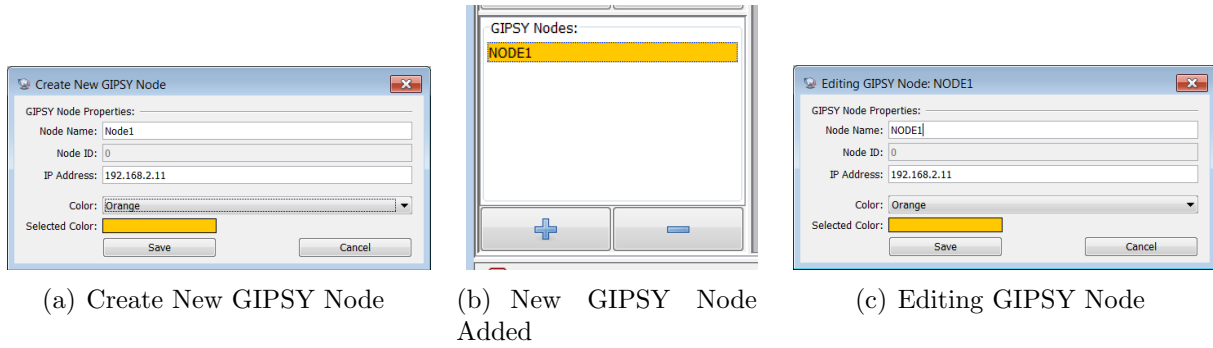


Figure 5: Creating and Editing a GIPSY Node

III. *Creating/Editing a GIPSY tier*

While editing, a GIPSY tier is represented as a red graph node. To create a GIPSY tier, the user must double-click on the highlighted area as shown in Figure 6(a). Then, the tier properties such as the tier name, how many instances to create, GIPSY instance to which the tier belongs to, GIPSY node on which the tier will be allocated, and finally a configuration file should be specified, cf. Figure 6. To edit a given tier's properties, right-click on a graph node and select "Edit Tier Properties", see Figure 7(b).

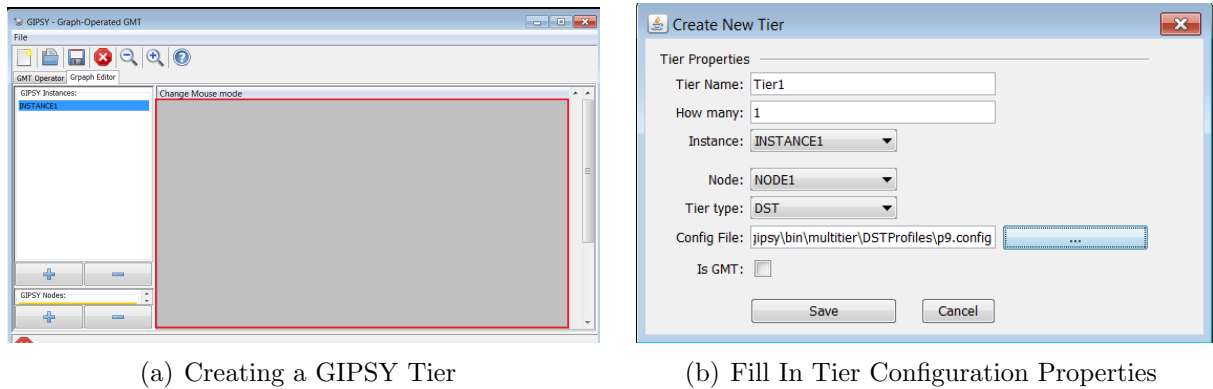


Figure 6: Creating and Configuring a GIPSY Tier

A.2 Saving/Loading a graph

To save/load a network to/from a file, use the save/load buttons located in the toolbar, Figure 8(a) and Figure 8.

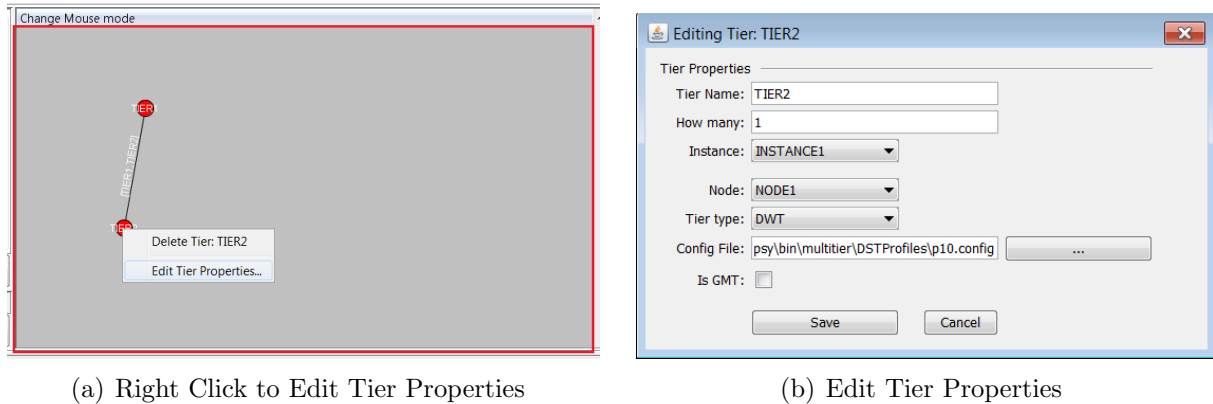


Figure 7: Editing Tier Properties

A.3 Using the GMT Operator

This feature is implemented in the “GMT Operator” tab and enabled upon loading a valid saved network graph. After loading is complete, the graph nodes (GIPSY Tiers) have the same color as the GIPSY node they belong to. Tiers’ shapes, as mentioned early in this paper, indicate what GIPSY Tier belongs to what GIPSY Instance.

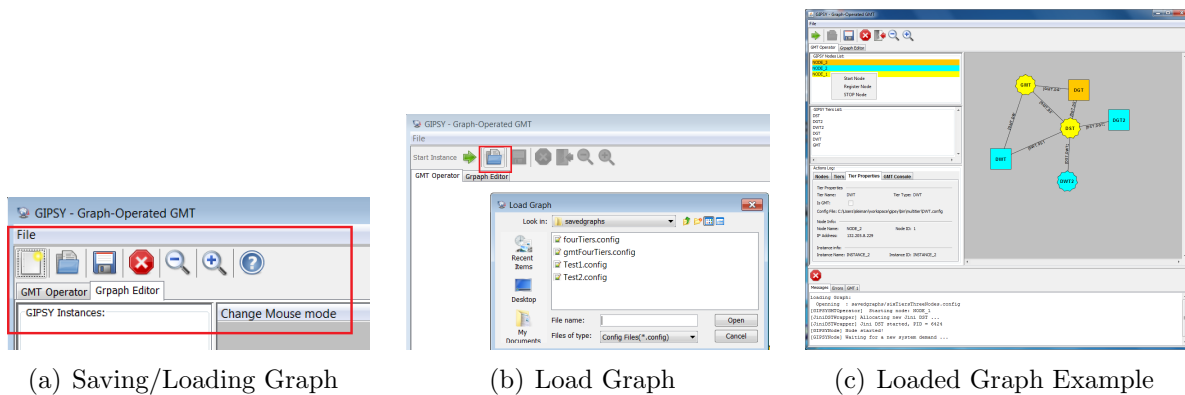


Figure 8: Saving and Loading GIPSY network Graph

I. Starting/Stopping a GIPSY node

To start a GIPSY node, right-click on a item in the nodes list and select “Start Node”, Figure 9(a).

After starting the first GIPSY Node, the actions taken are logged in the log console in “Messages” tab.

When the GMT is first started, a new tab is added to the log console where its activities are logged, see Figure 9.

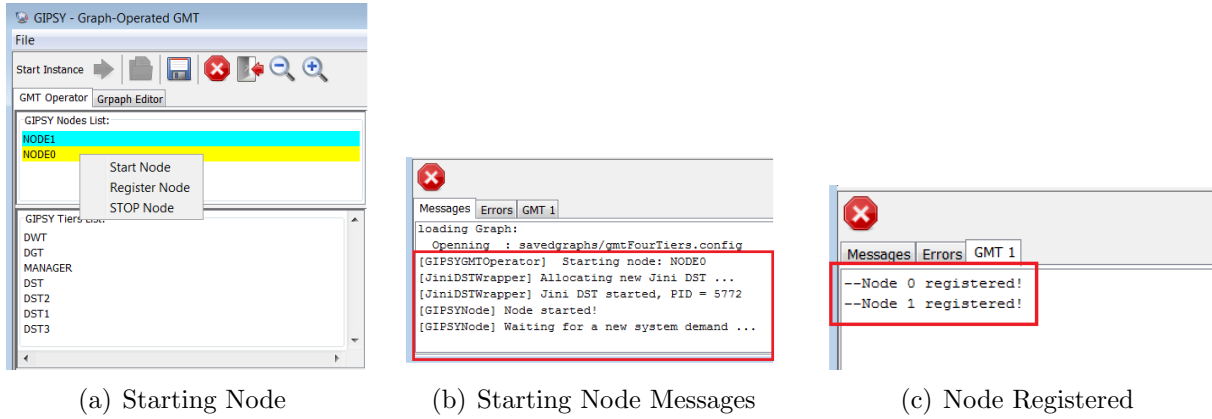


Figure 9: Saving and Loading GIPSY network Graph

II. Allocation/Deallocating GIPSY tier

To allocate or deallocate a GIPSY Tier, right-click on a graph node and select the appropriate action, Figure 10(a). The messages and action triggered by the allocation/deallocation process are logged and showed in the console tab, Figure 10(b), Figure 11.

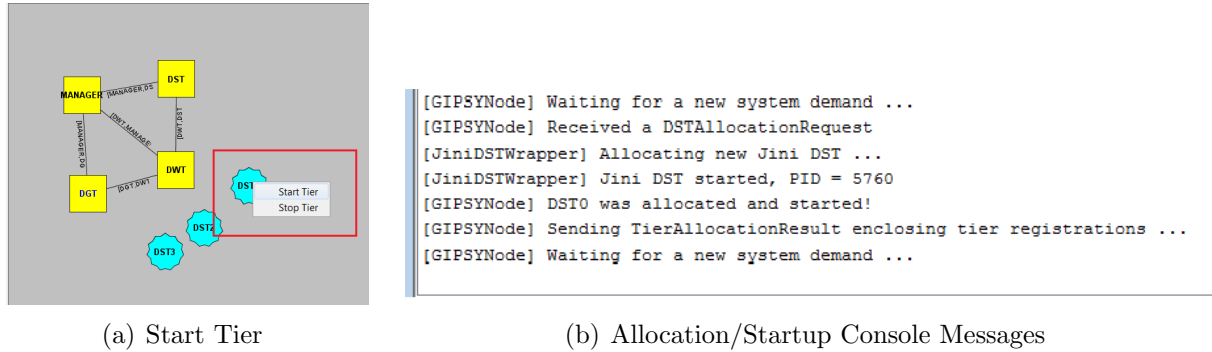


Figure 10: Starting a Selected Tier

B Stored Graph Example

In the example below is a concrete on-disk representation of the GIPSY network graph from `marfcatsome.config` that can be stored and retrieved and executed instantiating the designed configuration and its connectivity for the MARFCAT test case with the corresponding graph in Figure 12.

```
#Graph data
#Mon Jun 25 23:04:50 EDT 2012
```

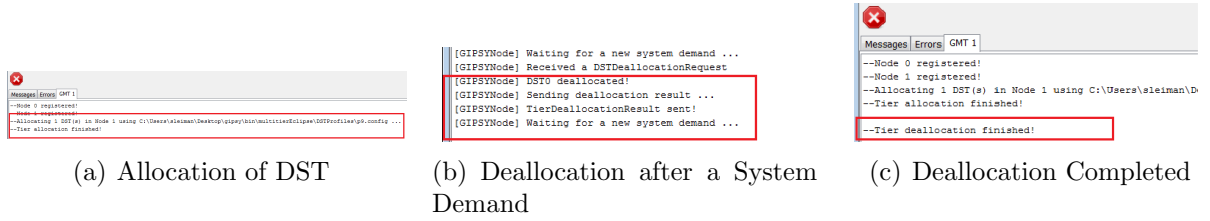


Figure 11: Allocation and Deallocation of a DST

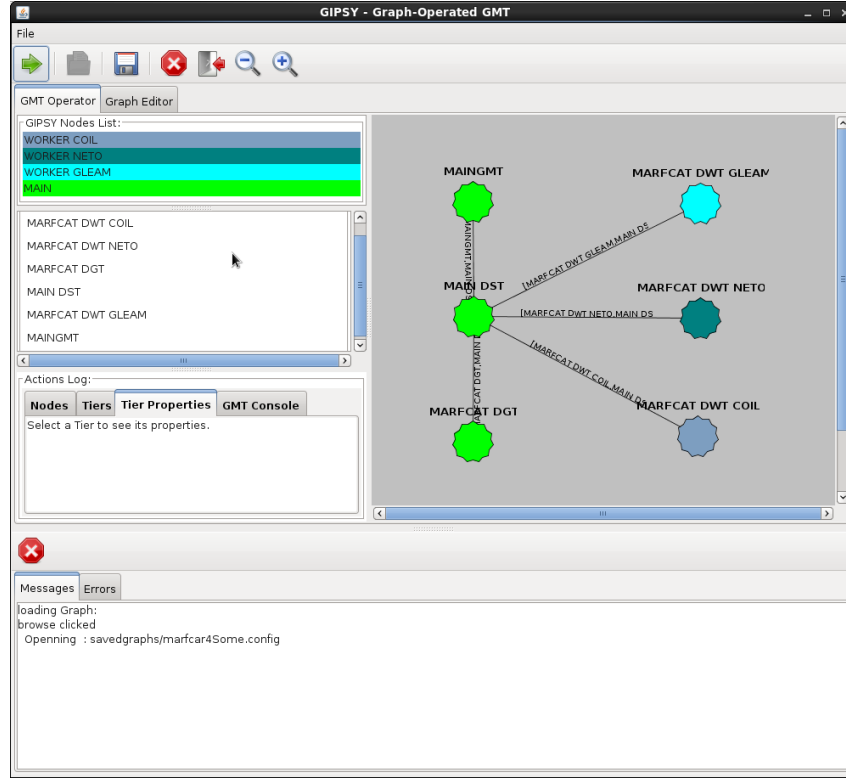


Figure 12: MARFCAT GIPSY network Graph

```

gipsy.tier.posx.a409cb6b-ad54-41f6-af69-f4ec78628ec6=405
gipsy.tier.isgmt.89e6605e-5c81-4d95-bf51-8e7576c8dcd7=false
gipsy.tier.ID.1523569d-25aa-44a4-97d5-370b93790333=1523569d-25aa-44a4-97d5-370b93790333
gipsy.tier.posx.89e6605e-5c81-4d95-bf51-8e7576c8dcd7=409
gipsy.connection.to.7802414d-437f-4382-9162-15d9d8e735c3=77fd90ec-e49e-4977-a55b-0690e2e0cd08
gipsy.tier.howmany.a409cb6b-ad54-41f6-af69-f4ec78628ec6=1
gipsy.tier.isgmt.c341ab91-161e-419d-a7e4-6206e75ec097=false
gipsy.tier.howmany.89e6605e-5c81-4d95-bf51-8e7576c8dcd7=1
gipsy.tier.node.1523569d-25aa-44a4-97d5-370b93790333=1
gipsy.tier.posx.c341ab91-161e-419d-a7e4-6206e75ec097=74
gipsy.tier.howmany.c341ab91-161e-419d-a7e4-6206e75ec097=1
connection_key.Odd7156f-3b40-4df7-b9a9-d1b44eeb4da0=Odd7156f-3b40-4df7-b9a9-d1b44eeb4da0
gipsy.node.name.3=WORKER COIL
gipsy.node.name.2=WORKER NETO
gipsy.tier.posy.1523569d-25aa-44a4-97d5-370b93790333=55
gipsy.node.name.1=WORKER GLEAM
gipsy.tier.isgmt.77fd90ec-e49e-4977-a55b-0690e2e0cd08=false
gipsy.node.name.0=MAIN
gipsy.tier.posx.77fd90ec-e49e-4977-a55b-0690e2e0cd08=75
gipsy.connection.to.Odd7156f-3b40-4df7-b9a9-d1b44eeb4da0=77fd90ec-e49e-4977-a55b-0690e2e0cd08
gipsy.tier.howmany.77fd90ec-e49e-4977-a55b-0690e2e0cd08=1
gipsy.tier.node.29310d89-fd7a-498c-8a47-f80d3b5b9865=0
gipsy.connection.id.1eeea2b5-ec50-4990-a7fe-be48bb5b693e=1eeea2b5-ec50-4990-a7fe-be48bb5b693e
gipsy.tier.tiertype.a409cb6b-ad54-41f6-af69-f4ec78628ec6=DWT

```

```

gipsy.tier.posy.29310d89-fd7a-498c-8a47-f80d3b5b9865=53
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gipsy.tier.isgmt.1523569d-25aa-44a4-97d5-370b93790333=false
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gipsy.connection.name.6a9e123b-c375-4786-9d15-12faeee54c59=[MARFCAT DGT,MAIN DST]
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gipsy.tier.howmany.29310d89-fd7a-498c-8a47-f80d3b5b9865=1
connection_key.6a9e123b-c375-4786-9d15-12faeee54c59=6a9e123b-c375-4786-9d15-12faeee54c59
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gipsy.tier.instance.c341ab91-161e-419d-a7e4-6206e75ec097=8f5d7614-49e9-4c8a-87fe-c8032a5c9009
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gipsy.node.color.2=Teal
gipsy.node.color.1=Blue
gipsy.node.color.0=Green
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gipsy.tier.configfile.1523569d-25aa-44a4-97d5-370b93790333=/local/data/gipsy/cvsccheckout/gipsy/gipsy/bin/multitier/marfcataDWT.config
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gipsy.connection.from.36485580-5acf-4c12-9110-47c60e23ddc9=89e6605e-5c81-4d95-bf51-8e7576c8dcd7
gipsy.tier.configfile.29310d89-fd7a-498c-8a47-f80d3b5b9865=/local/data/gipsy/cvsccheckout/gipsy/gipsy/bin/multitiermarfcata/GMTNode.config
gipsy.connection.name.0dd7156f-3b40-4df7-b9a9-d1b44eeb4da0=[MARFCAT DWT GLEAM,MAIN DST]
connection_key.7802414d-437f-4382-9162-15d9d8e735c3=7802414d-437f-4382-9162-15d9d8e735c3
gipsy.tier.posy.89e6605e-5c81-4d95-bf51-8e7576c8dcd7=224
gipsy.tier.posy.77fd90ec-e49e-4977-a55b-0690e2e0cd08=222
gipsy.tier.isgmt.a409cb6b-ad54-41f6-af69-f4ec78628ec6=false

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